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Quantitative Analysis of Auroral Oval Dynamics

C. Robert Clauer, Principal Investigator
Linnea Nooden, Graduate Student Research Assistant

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The University of Michigan
Space Physics Research Laboratory

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1. Introduction and Objectives

With the increase in the number of satellites and the increasing time resolution of the data acquired from them, there are a great number of data which have not yet been analyzed. The Dynamics Explorer - 1 Scanning Auroral Imager (DE-SAI) instrument alone has sent back more than 600,000 images in the UV and visible ranges of the spectrum. More recent and future missions provide higher temporal and spatial resolution images with the associated increases in data management and analysis problems. A possible solution to some of these problems is a method to semi-automate or completely automate initial processing and extraction of meaningful scientific parameters from the auroral images. This project utilized DE-SAI data and prototype software to extract global auroral parameters and to calibrate the results against different data sets. Such physical parameters could have a wide range of uses from global event characterization (like the AE index) to providing useful inputs to models of the magnetosphere, ionosphere, and upper atmosphere.

For example, we defined the 'auroral cap' boundary and area (the region poleward of the auroral oval) as parameters which could be determined by computer algorithms. Such parameters could be computed from future missions such as POLAR to provide unique global activity parameters. Currently, the most widely used index of magnetospheric activity is the magnetic AE index. However, this index is frequently a poor index because of limitations in the distribution of magnetic observatories and the rapid availability of data from the multiple sites required to compute the index. The index is particularly poor during times when the polar cap is especially small or large. At these times the auroral electrojets can completely miss the network of AE stations. A global (hemispheric) index from a single data source could overcome many of these limitations.

The objectives of the project were to utilize prototype software developed under NASA support at Stanford University to compute the auroral cap boundary and area from a large number of DE-SAI images. The boundaries obtained through computer methods would be checked for accuracy to determine the efficacy of the software, and then the auroral cap boundary locations would be calibrated against other more established boundary parameters. We used the 'aursoft' program developed at Stanford University to automatically determine the optical auroral boundaries. In addition, we used several programs to interpret the auroral boundaries and compare with other data sets.

2. Methods

2.1 Aursoft

Aursoft is a collection of routines written in C by D. Mihovilovic as part of his Ph.D. research at Stanford University (Mihovilovic, 1992). These programs take raw data images (in mission analysis file format, MAF) from the DE-SAI instrument and attempt to determine both inner and outer auroral boundaries of the aurora. This is accomplished by first determining a 'best fit' oval using a least squares method producing an ellipse through the auroral maxima. Then the data are scanned radially inward and outward from this auroral oval to determine the boundary. The boundary is identified as a drop in emission intensity by a certain percent. The percent value is determined adaptively. In general, we have found that this method does a moderate job

2.2 Other Programs

A program using IDL has been developed to read the output of the aursoft program. It reads the binary image file and the boundary locations and displays the auroral images and boundary locations. It is also able to read in boundaries obtained from DMSP satellite particle precipitation data and overplot these boundaries on the auroral images. The program provides the optional transformation to view all images from a point at a fixed altitude directly above the magnetic pole.

An unfinished portion of the program is meant to determine distances between DMSP particle boundaries and auroral boundaries. This difference was to become the basis for developing a statistical calibration of the auroral boundaries to the DMSP determined particle boundaries which have come into wide use within the community to define the mapping between the ionosphere and outer magnetospheric regions.

2.3 Neural Nets

The difficulties encountered in using the poorly documented aursoft software and its output resulted in an effort to determine auroral boundaries using another technique -- neural nets. A neural net is an algorithm which takes an input and through a series of calculations of 'layers' determines an output.

The neural net used in this case is a one dimensional net. The neural net creates a set of equations which, in its learning stage, takes the input and target output arrays and computes weights relating the two. It does this through many sample iterations until stable values of the weights are obtained. When the weights have converged to within a given criterion, the network is said to be trained.

Training sets must be large containing 1000 or more sample inputs - output pairs, and the problem must be chosen or visualized properly. The problem must be simplified into something visually straightforward to the human eye. In our case, the data used to train and test the neural network are from an auroral image that has been 'unwrapped'. That is, r and θ (cylindrical coordinates) have been put along the x and y axes. Each slice along θ is used as a separate input. For training purposes, a corresponding 0 or 1 is placed in an array with each point corresponding to each point in the input array. Regions of aurora are indicated by 1 and lack of aurora are indicated by 0.

3.0 Progress

We obtained only limited success using the aursoft program. The program is acknowledged to fail to produce satisfactory boundaries under some conditions, including weak aurora, aurora obscured by solar illumination (summer hemisphere), and θ aurora. We have found that the program also seems to fail when the aurora is extremely bright. The outer boundaries are generally poor, but the inner boundaries are often acceptable or require only little adjustment. Our calibration, therefore, was to focus upon the inner auroral boundaries and the area of the 'auroral cap'.

Calibration of the auroral boundaries with DMSP particle boundaries obtained from Pat Newell has not been completed. Initial comparisons resulted in the discovery of a problem with coordinate locations. Following the resolution of this problem and verification of the solution using a small number of images, little time in the support remained to complete the calibration.

Some limited success has been achieved from the use of the neural network approach. There are still a number of refinements required, however. Suggested further investigation of this approach might include:

1. The use of a two dimensional neural network. While taking longer to train, such a neural net should improve boundary determination since there is a strong correlation between boundaries in both latitude and longitude.
2. Greater care should be taken in developing the training set. Our set was assembled quickly to determine if the method showed promise.
3. Our training set included only 300 samples, so a larger training set containing 1000 samples should be developed.

4.0 Conclusion

The project resulted in only a mixed success and did not reach a final conclusion. While we feel that the project is worthwhile for the reasons stated above in the Introduction, the present state of the software is not satisfactory for use by the scientist. Additional programming effort is required to assemble the algorithms into an application that can be utilized by a scientist for analysis of the data and to complete the calibrations attempted here.